# SOLVING A NURSE SCHEDULING PROBLEM AT A 24 HOUR CLINIC USING INTEGER LINEAR PROGRAMMING

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## 1. Introduction

Nurse scheduling problem (NSP) is important in assigning every nurse at a specific place and appropriate times. It is a complex exercise with multiple and contradictory objectives minimizing total costs while maximizing the nurses' preferences and requests, and equally distributing workload between nurses. Constraints in nurse scheduling relate to requirements for each shift that can be assigned to each particular nurse, maximum number of consecutive days of work, minimum amount of rest time between two shifts, and isolated days of work or days-off. The time and effort were utilized efficiently in order to balance the workload to lead to more contented and effective nurses (Kumar et al., 2014). El Adoly (2018), studied the scheduling process of nurses in a hospital in Egypt and found that the proposed model decreases overall overtime cost by 36%. This study focused at creating an optimum nurse schedule that minimize cost and employs the integer linear programming model for solving nurse scheduling problems. This study applied primary data which was collected from a selected 24-hours clinic in Seremban, Negeri Sembilan.

## 2. Methodology

The data and characteristics of nurses' timetabling problems are collected from the polyclinic which consists of the number of nurses, working day and shifts. Since the shift is divided into three shifts; morning, afternoon and nights, the planning horizon for one week is 21 shifts during the planning horizon. The problem is to ensure that each nurse works between six to eight shifts a week, the nurses work one shift without having two successive shifts off. Moreover, the nurses cannot work more than 52.5 hours per week. The integer linear programming for the NSP at the clinic after taken into consideration all the constraints exists and the rules of the clinic can be defined by the following sets of model formulation:

$c_1$ : Cost per shift of a nurse
$c_2$ : Overtime cost per shift of a nurse
$I$ : Set of nurses {1, 2, 3}
$J$ : Set of shifts {1, 2, 3..., 21} during the planning horizon
$U_i$ : Maximum number of shifts that nurse (i) can work during the planning horizon.
$N_i$ : Number of shifts that nurse (i) should work during the planning horizon.
$M_j$ : Number of nurses required for shift (j).
$A$ : Minimum number of afternoons shifts that a nurse should work.
$B$ : Minimum number of night shifts that a nurse should work.

In this model, the decision variable is the number of nurses assigned at shift specified where value 1 is assigned as when there is a nurse attending on a specific shift while 0 is if there is an absence of nurse at a specific shift. The variable is compress in an equation defined as follows:

**Decision variables:**

$$x_{ij} = \begin{cases} 1, & if\ nurse, i\ are\ assigned\ to\ shift\ j \\ 0, & otherwise \end{cases}$$

**Objective function:**

$$Min\ Z = \sum_{i=1}^{I}\sum_{j=1}^{J}(c_1 * x_{ij}) + c_2\left[\left(\sum_{i=1}^{I}\ \sum_{j=1}^{J}\ x_{ij}\right) - N_i\right]$$

**Constraints:**

$$\sum_{i=1}^{I} x_{ij} \geq M_j \quad \forall j \in J \tag{1}$$

Ensures that the required number of nurses in each shift is satisfied.

$$\sum_{i=1}^{J} x_{ij} \geq N_i \quad \forall i \in I \tag{2}$$

Ensures that each nurse has a minimum number of working shifts.

$$\sum_{i=1}^{J} x_{ij} \geq U_i \quad \forall i \in I \tag{3}$$

Ensures that each nurse has a maximum number of working shifts. A nurse has to work a number of shifts within these limits.

$$\sum_{j=0}^{\frac{J}{3}-1} x_{i(3j+2)} \geq A \quad \forall i \in I \setminus \{1,2,\dots,I\} \tag{4}$$

Ensures that each nurse must work at least a minimum number of afternoon shifts.

$$\sum_{j=1}^{\frac{J}{3}} x_{i(3j)} \geq B \quad \forall i \in I \setminus \{1,2,\dots,I\} \tag{5}$$

Ensures that each nurse must work at least a minimum number of night shifts.

$$x_{ij} + x_{i(j+2)} \leq 1 \quad \forall i \in I \setminus \{1,2,\dots,I\} \quad \forall j \in J \setminus \{1,2,3,\dots,J-2\} \tag{6}$$

Ensures that a nurse will have at least two successive shifts off if he/she works for one shift.

## 3. Results and Discussions

Table 1 shows the working shift and the overtime shift of the nurses for a week. It can be seen that each nurse takes at least one day off in a week. Looking at the On Duty cell in Table 4.1, each nurse works 6 to 8 days shift in a week. Besides that, each nurse takes at most two consecutive shifts only per week.

**Table 1.** Nurse Schedule in a Week

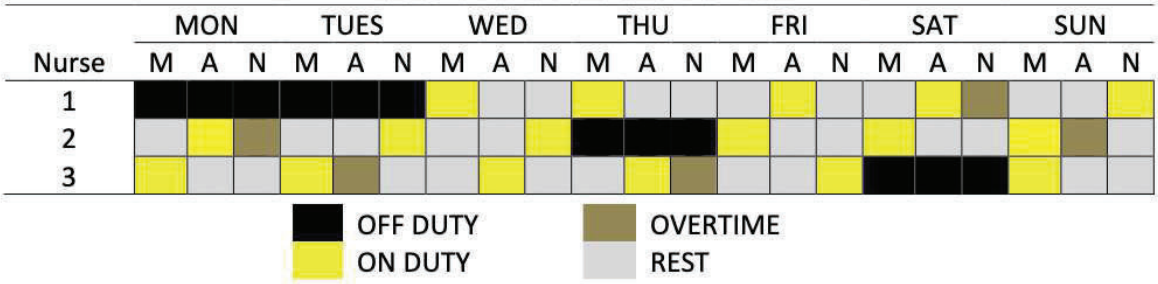


**Table 2.** Nurse Schedule in a Month

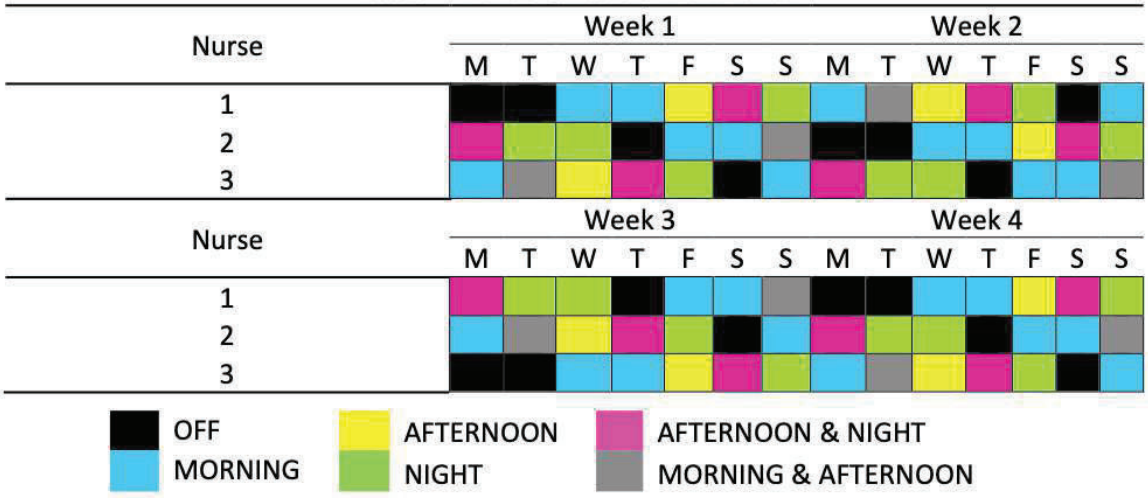


Table 2 shows the working schedule for three nurses in one month. The objective of this study is to minimize the total cost of assigning nurses to shift. The assignment of nurses to the shifts has been improved as the average working shift per nurse is 7 shifts weekly per nurse, thus the cost

is reduced by 7.14% monthly which is from RM3,360 to RM3,120. The polyclinic can save up to RM250 each month to pay for shifts.

Figure 1 depicts all nurses are assigned the same number of working shifts, overtime shifts and number of shifts off. All constraints are satisfied and imply that the nurses' preferences have been improved.

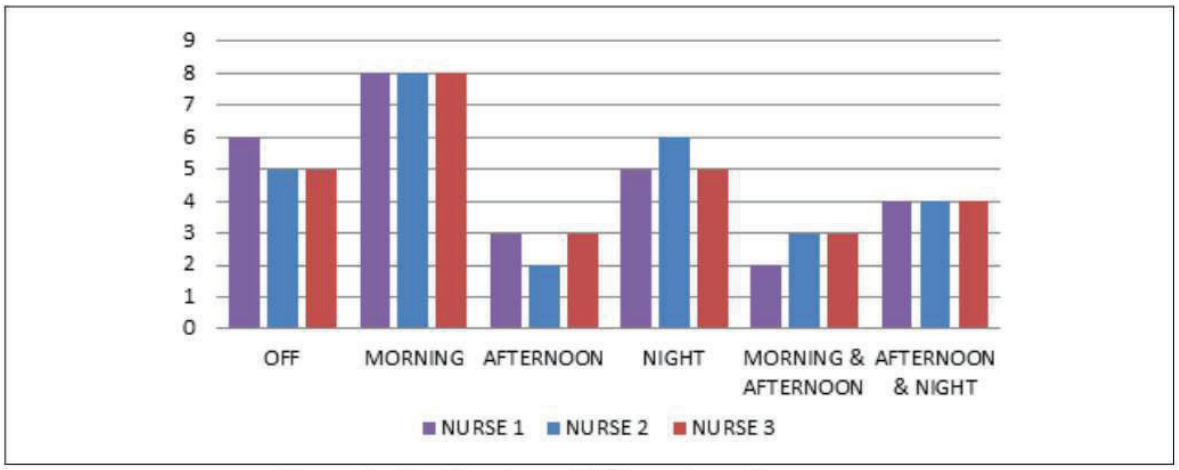


**Figure 1:** The Number of Shifts assigned to nurses

## 4. Conclusion

This study is focusing on the nurse scheduling problem where it is crucial in the management of hospitals and clinics. In this study, a formulation which is based on an integer linear programming model was applied in order to solve the scheduling problem. The model considers all the constraints related such as the government regulation, hospital and clinic regulation and the standard global rules and regulations. This model was verified by applying it in the real case study involving a 24-hours polyclinic in Seremban, Negeri Sembilan and produced a fair and feasible schedule for all the nurses besides minimizing the cost of the clinic.

## References

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